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Some Aspects of an Early Expression of dominance in White Pine (Pinus strobus L.)

J Lee Deen

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SOME ASPECTS OF AN EARLY EXPRESSION OF DOMINANCE IN WHITE PINE

(*PINUS STROBUS* L.)

BY

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FOREWORD

THE original manuscript covering this investigation was submitted as a dissertation in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Yale University and was written under the direction of the late James W. Toumey, Sc.D., F.D., Morris K. Jesup Professor of Silviculture, Yale University, from whom numerous helpful suggestions were received. The writer wishes to acknowledge the many constructive criticisms made by Ralph C. Hawley, M.F., M.A., Professor of Forestry, Yale University, in the preparation of the manuscript for publication.

SOME ASPECTS OF AN EARLY EXPRESSION OF DOMINANCE IN WHITE PINE
(*PINUS STROBUS* L.)

INTRODUCTION

CASUAL observation reveals that trees in a pure, evenaged stand are divided into various size groupings, diameter and crown classes being the more commonly recognized. A distribution chart of the number of trees in the various size classes follows quite closely the curve of normal error. In or near the center of the grouping is the greatest number of trees, and their number decreases more or less rapidly, both into the larger and into the smaller sizes. This division of evenaged stands into size classes is the result of an unequal growth rate in the individuals and has been termed an *expression of dominance*. The more regular the stand, the more the trees are crowded into relatively few size classes and the weaker the expression of dominance.

Two extremes can be recognized in the development of forest stands when differentiation into crown classes is considered. (1) Dominance may be clearly expressed, but the dominants are too few in number. In such instances some few individual stems have taken command of the situation and with overlarge, vigorous crowns completely dominate their slower growing neighbors. Hauch (1912) found this condition to exist in some of the beech stands in Denmark. (2) Dominance may be poorly expressed. When this condition prevails, no individuals stand out, the crowns are almost uniform in size, and the intense competition which sets in at the time of crown closure causes all trees to suffer very nearly alike. Jack pine (*Pinus banksiana* Lambert) frequently forms stands of this nature on poor, sandy soils. Between the two extremes are found the stands in which there is an acceptable expression of dominance.

PLAN OF STUDY

THE ideal procedure in a study of an early expression of dominance would be to lay out permanent sample plots at the time the seedlings become established and follow them through for a definite period much after the manner of Hauch (1912) in his study of oaks. Such a procedure was impossible in this study, and therefore a series of temporary plots was substituted.

A study was made of these plots for the purpose of observing and noting (1) the factors affecting an expression of dominance in white pine (*Pinus strobus* Linnaeus) and (2) the relationship between dominance and the development of white pine stands.

The principal field studies were made during the summers of 1929 and 1930 and were supplemented by additional observations made in 1931 and 1932. In all, thirty-three plots were taken, twenty in natural stands and thirteen in plantations. Four plots in natural stands were rejected later because they were either mixed stands or unevenaged.

Although it was recognized that stands composed exclusively of white pine would be preferable, it was found to be impossible to locate a sufficient number of such plots, and therefore arbitrary standards for a pure stand were set up. The requirements for a pure stand were varied with the character of the other tree species present. If the other species were those which occupy a temporary position in the stand, such as gray birch (*Betula populifolia* Marsh) or largetooth aspen (*Populus grandidentata* Michaux), the stand was considered pure when 85 per cent or more of the stems were of white pine. If the other species were those which occupy a permanent position in the stand, such as hemlock (*Tsuga canadensis* [Linnaeus] Carrière), the stand was considered pure when 95 per cent or more of the stems were white pine.

The greatest variation in age accepted was 15 years. During the preliminary stages of the investigation a much narrower range was set up; namely, 5 years. It was soon recognized, however, that a range of more than 5 years was a characteristic feature of evenaged white pine stands in the region covered,[1] especially during the juvenile stage. As the stand advances in age, the younger stems, which occupy a subordinate position in the stand, are eliminated and the range in age is narrowed.

ENVIRONMENTAL CONDITIONS

THE study was made in southern New Hampshire and on selected areas in Vermont, well within the optimum range of white pine. The area in which most of the plots are located lies in the Ashuelot Valley in

[1] The reasons for this are discussed at length on page 14.

the towns of Swanzey and Keene, New Hampshire. The soil is light, consisting chiefly of a homogeneous, fine to coarse, sand, which Hawley (1927) states is one of the distinct site classes within the New England white pine region. Craib (1929) states that at times there is a deficiency of available moisture in the soil. The site index at 50 years falls consistently between 45 and 65 feet. Although the surface is fairly level and reasonably free from stone, this soil is generally considered rather light for agricultural use.

The mean annual temperature at Keene, 1916 to 1928 inclusive, was 45° F., and the mean annual precipitation over the same period was 39 inches (Toumey, 1932). There is a wide daily range in temperature during the growing season. The nights are cold and frosts may occur in any month of the year. The first heavy frosts in autumn generally occur about the middle of September. The precipitation shows a remarkably even distribution throughout the year when based on monthly averages over a period of years.

Six of the sample plots are in the Connecticut Valley, approximately 15 miles northwest of Keene. The climatic and physiographic conditions are much the same as those described above.

HISTORICAL REVIEW

A CLASSIFICATION of crown classes was stated in forest terminology as early as the sixteenth and seventeenth centuries (Lönnroth, 1926:6). The first reference to an ability to express dominance, however, was made in 1899 by Hauch and Oppermann (1898–1902:101). They used the term *Spredningsevne,* which they defined as a tendency for some individuals of a stand to develop more rapidly than others, thus bringing about a distribution into different diameter classes.

Hauch (1910) continued his studies on dominance and later stated that an expression of dominance is more pronounced in beech, oak, and Scotch pine than it is in spruce and ash. After a series of investigations at Bregentved he concluded that an expression of dominance varies with sites, species, and races (Hauch, 1912, 1918).

Spalding and Fernow (1899) recorded reduction with increasing age in the number of trees composing a stand and assigned this reduction to failure in the competition for light on the part of some individuals. More recent investigations, such as those carried out by Fricke (1904), Tourney (1929), Grasovsky (1929), Toumey and Kienholz (1931), and others, point out that other environmental factors may be equally important. Aaltonen (1926) attributes space arrangement within the stand chiefly to root competition. Gevorkiantz and Hosley (1929) conclude that growing space controls crown and root development and the chance of the individual for dominance.

It appears that it is a complex of factors which brings about the dominance of its neighbors by an individual stem. Toumey (1928: 324) recognized this and stated that the size of each particular individual in an evenaged stand depends upon (1) its inherent capacity for growth, (2) the degree of competition, and (3) the favorableness of its particular location.

CRITERIA OF AN EXPRESSION OF DOMINANCE

THERE are numerous criteria which may be used to denote the degree of differentiation or uniformity in forest stands. The average diameter[2] can be used as an index of the present condition of a stand, provided the average age is known. A stagnating stand will have a low average diameter for its age. Average diameter, however, does not indicate the diameter distribution within a stand. Density of stocking,[3] basal area, and cubic volume are all open to the same criticism as average diameter, since they do not indicate the variation in size of the individuals composing a stand.

Standard deviations of total height, crown spread,[4] and diameter are all measures of variation in size of the trees composing a stand. A high standard deviation for a specific age in any of these three measurements denotes a strong expression of dominance. Of the three, diameter is the one most frequently used by foresters and is most readily obtainable. An exception is found in young stands which have not developed sufficiently to have a measurable diameter, breast high. In such stands it was found possible to use the standard deviation of diameter at 6 inches above ground. A choice among the three measurements of total height, crown spread, and diameter is governed chiefly by expediency in the particular work at hand.

2 Diameter as used in this paper, unless otherwise modified, refers to diameter, breast high, *i.e.*, 4½ feet above the ground.

3 Density of stocking as used in this paper refers to the number of trees per acre.

4 Average diameter of the crown.

STANDARD DEVIATION OF DIAMETER, BREAST HIGH

Standard deviation of diameter denotes the degree of dispersal around the average diameter and, according to Meyer (1930), normally increases with increasing diameter.

Since standard deviation is affected by increasing diameter, it must be supplemented by further information before it can be used as a criterion of differentiation or uniformity. Average age supplies the needed data. Plot 8 is shown in the Appendix to have an average diameter of 1.9 inches and a standard deviation of diameter of 0.S5. Plot 22 has an average diameter of 3.4 inches and a standard deviation of 1.48. The difference in average diameters, unassociated with average age, would seem to indicate that the standard deviations of the two plots are not comparable because standard deviation increases with increasing diameter. They are comparable, however, because the two plots are both 27 years old and with equal development would have the same average diameter. The unequal development in this example is probably due in part to site quality (see Source Data in Appendix). The influence of site and of other factors in this connection is discussed under a later heading.

Plot 22 is widely differentiated as is indicated by a standard deviation of 1.48. Its average diameter is approximately the same as the normal given by Frothingham (1914). In Plate II, No. 1, the dominant trees in Plot 22 are shown to be too widely distributed and are developing with large, heavy branches. The dominants are too few in number. Plot 8 is uniform, as indicated by a standard deviation in diameter of 0.55. Its average diameter is considerably below the normal given by F'rothingham (1914). In Plate II, NO.2, the dominant trees in Plot 8 are shown to be too great in number and crowded. The developlnent of the two plots has not been the same.

The source data show that of the planted stands Plot 15, which is spaced 4 X 4 feet, has a standard deviation of 0.65, while Plots 31 and 34, which are spaced 6 X 6 and 8 X 8 feet respectively, both have a standard deviation of 0.52. A stand table shows that Plot 15 has as many stems per acre in the larger diameter classes as the other two plots and has the added advantage of denser stocking. Plot 15 appears to be the most desirable of the three plots at the present time.

Standard deviation of diameter is closely related to other features of a stand as evidenced by the following table:

CORRELATION BETWEEN STANDARD DEVIATION OF DIAMETER AND OTHER FEATURES OF THE STAND[5]

	Coefficient of correlation
Density of stocking	
Natural stands	—0.82
Planted stands	
Group 1	+0.46
Group 2	—0.99
Average growth for last 10 years on the radius of dominant trees	
Natural stands	+0.87
Standard deviation of height	
Natural stands	+0.84
Planted stands	+1.00
Standard deviation of crown spread	
Natural stands	+0.84
Planted stands	+0.83

The coefficients of correlation show an intimate relationship to exist, in the stands studied, between standard deviation of diameter and other features of the stand. The correlations show that standard deviation of diameter is indicative of other variations which typify the degree of dominance.

The coefficient of correlation between density of stocking and standard deviation of diameter is minus in natural stands and in Group 2 of the planted stands. This denotes that standard deviation of diameter decreases with increasing density of stocking in natural stands and in Group 2 of the planted stands. The opposite is true in Group 1 of the planted stands which is younger than Group 2. The seeming discrepancy is probably due to the fact that competition has not progressed sufficiently in Group 1. As the plantations become older the standard deviation of diameter takes the same trend as in natural stands.

The average growth on the radius of dominant trees for the 10 years

[5] From Table I, Appendix.

immediately prior to measurement is closely linked with standard deviation of diameter as is evidenced by a coefficient of correlation of +0.87.

The coefficient of correlation between standard deviation of diameter and standard deviation of height is +0.84 in natural stands and +1.00 in plantations. These correlations show that variations in height are accompanied normally by variations in diameter.

The coefficient of correlation between standard deviation of diameter and standard deviation of crown spread is +0.84 in natural and +0.83 in planted stands. A variation in the crown spread represents a variation in the photosynthetic equipment of individual trees. The coefficients of correlation of +0.84 and +0.83 show that there is a distinct relationship between variation in crown spread and variation in diameter.

The relationship between crown spread and diameter is direct. The coefficient of correlation between average crown area[6] and average basal area is +0.84 for natural stands and +0.94 for plantations. (Table I, Appendix.) Since this relationship exists, the tree with the greater diameter can normally be expected to have the greater crown spread. There also is a direct relationship between diameter and weight of the above-ground portion of a tree. Collison and Harlan (1930), working with apple trees, obtained a coefficient of correlation of +0.97 between mean trunk circumference and the weight of the main stem and branches.

Because standard deviation of diameter can be obtained readily and because it is closely related to other features of the stand which measure the dominance, standard deviation of diameter, breast high, is believed to be a good criterion of differentiation.

A table giving the optimum ranges of standard deviation of diameter, breast high, for definite age classes would be highly desirable. Although the data on which this paper is based permit the recognition of extremes in an expression of dominance, they are not sufficiently comprehensive to permit the delimitation of optimum ranges.

[6] Crown area as used in this paper designates the area of a circle which has crown spread as its diameter. Crown area is sometimes referred to as the surface area of a cone which has crown depth as its height and crown spread as the diameter of its base. An attempt was made to correlate crown area as used in the latter sense with diameter, breast high, but no significant correlations could be found. Just why this should be is rather difficult to explain. The writer believes that a comparison of this kind made between trees growing in the open, free from the complications set up by intimate contact in stands, would yield significant results.

FACTORS AFFECTING AN EXPRESSION OF DOMINANCE

Inherent Characteristics

THE ability of a species to express dominance is dependent (1) on inherent tendencies and (2) on the environmental factors which modify the expression of inherent tendencies. The ability of one tree to grow more rapidly than its neighbors of the same species and under the same conditions is due to a variation in genotypes within the species. This has been brought out by Hauch (1912, 1918) in his studies on dominance. He followed the development of spruce and beech in seedbeds, in an instance where these seedlings were not used in field planting but were left in the nursery to form stands. He states that the spruce showed much more uniform growth and development than the beech. The growth almost ceased in the spruce, while the beech, handled in the same manner, produced an excellent stand. He explains the difference in development on the basis of variations in genotypes. The factorial make-up of the spruce was such that the genotypes were fairly homogeneous, while the beech seedbed was a composite of heterogeneous genotypes.

Hauch also found a variation in the genotypic homogeneity between races within a species. He collected acorns from various parts of Europe and planted them under the same conditions. At the end of 19 years he found a wide range in the expression of dominance between the different plantations. He also carried out a somewhat similar experiment with local races of beech, with the same result.

The technique of orcharding practice is bent towards securing uniformly vigorous trees. In spite of this fact there is considerable variation in size of the individual trees in an orchard. Collison and Harlan (1930) state that environmental factors may account for some of the individual variations in apple trees, but they believe that the larger part of the variation must be due to inherent individual variability in the trees themselves. If there is an inherent variation within orchards in which every attempt is made to secure uniformity and in which new individuals are produced by grafting, there must be a greater inherent variation in natural forest stands in which there has been no cultural attempt made to secure uniformity in the seedlings.

It appears that the genetic factorial make-up of one individual may be such that it possesses a native ability for rapid growth which is more pronounced than that possessed by its neighbors. A potentiality for response is inherited. The response is modified by such factors as site, variation in age, density of stocking, and silvicultural treatment of the stand. The effect of modifying factors will be discussed under their respective headings.

As previously stated Hauch (1910), in Denmark, lists beech, oak, and Scotch pine as having greater ability to express dominance than spruce and ash. Amilon (1923: 61), in Sweden, states that dominance is expressed more markedly in birch, larch, oak, beech, and in the Scotch pine of central Sweden than in spruce, alder, ash, or maple, while fir and the Scotch pine of northern Sweden occupy an intermediate position. Hauch (1918) states that the Scotch pine of central and northern Sweden are of different races, hence the difference in their ability to express dominance.

From the present study it appears that white pine has the ability to express dominance in an acceptable manner whenever environmental conditions are not too unfavorable. Although comparison between white pine and other species was outside the scope of this study, observations by the author indicate that as a species white pine exhibits dominance more markedly than such associated species as jack pine or Norway pine (*Pinus resinosa* Solander). Further observation and study is necessary before the position of white pine in comparison with other species can be stated with exactness.

SIZE AND ORIGIN OF SEED[7]

No work was done in this study on the effect which size and origin of seed have on an expression of dominance, although the importance of these factors is recognized. Clark (19°4) states that seeds of low specific gravity do not germinate at all, while those somewhat heavier germinate sparsely and often produce weak plants. Cieslar (1923), Hauch (1923), Eitingen (1926), Korstian (1927), and others have investigated the relationship between size of acorn and size of seedling produced. They agree that the difference in early seedling growth favors the larger acorns, but they do not agree on later effects. Cieslar believes that the effect soon becomes of minor consequence, while Hauch, on the contrary, maintains that the effect persists markedly throughout the life of the tree.. Eitingen and Korstian, recognizing the complexity of the situation, express the opinion that, al-

7 Origin of seed is used here in a restricted sense. It refers to the collection of seed from a single tree or stand as compared to collection from two or more trees or stands.

though the early favorable effect is soon lost in open stands, the superiority at the start is especially significant in dense stands. It appears evident that the dominant trees in a stand will; for the most part, come from those seedlings which have had the better start.

Hauch (1912) states that an expression of dominance is influenced by the origin of the seed. A plantation established from the seed of one tree shows a weaker expression of dominance than one established from the seed of many trees. He further states that, as far as origin of seed is concerned, the expression of dominance is greatest when the seed is collected from several stands. He attributes this to a greater variation in genotypes.

SITE

Differentiation or uniformity are caused, in a measure, by site quality. Hauch (1912) states that an expression of dominance varies with site quality and that the expression of dominance is greater for the same species on the better sites.

Table I in the Appendix shows that the coefficient of correlation between site index at So years and standard deviation of diameter in the natural stands is +0.64 in Group 1 and +0.55 in Group 2. In the planted stands it is +0.61 in Group 1 and -0.68 in Group 2. The plots are divided into two relatively evenaged groups to make them comparable, Group 1 being roughly 10 years younger than Group 2. This division is made because standard deviation normally increases with increasing diameter and hence normally \vith increasing age, while the site index remains fixed.

Group 2 of the planted stands does not show a positive relationship between site index and standard deviation of diameter. This is probably due to the fact that these plantations are so widely spaced. The effect of density of stocking on standard deviation of diameter is discussed on page 19.

After the early stages of a stand's existence, poor sites normally have a greater number of trees per acre than good sites. This is well known by foresters and is recognized, among other places, in the construction of yield tables. During the period in which reproduction is being established the favorable elements of a good site usually make possible the establishment of more seedlings per unit of area than is possible on a poor site. After the phase of individual growth passes and root and crown closure takes place, competition is much keener on the good sites, and as a result natural elimination proceeds more rapidly than it does on poor sites. The poor site, with its paucity in nutrients and soil moisture, does not afford an opportunity for an individual with a potentially rapid growth rate to utilize this latent power (Büsgen and Münch, 1929: 410), and the stand develops with more or less uniformity. The individuals are less able to express dominance and thus force out their weaker neighbors. Competition affects all stems more nearly alike, the stand is non-differentiated, and stagnation results.

Minor local variations in the site may also favor one individual or small group of individuals against another. This is especially noticeable in plantations where a seedling or a group of seedlings is set in a small depression where soil moisture conditions are more favorable than in the surrounding area. Plantations normally develop rather uniformly, and the more rapid height growth of a favored individual or a favored group of individuals attracts the eye at once.

In this investigation all stands, with one exception,[8] having a site index at 50 years of 58 or higher showed an acceptable expression of dominance. It appears that stands with a site index at 50 years of 60 or more will show a suitable expression of dominance and that stands with a site index of 50 or below normally will not. Between the site indexes of 50 and 60 the differentiation or non-differentiation of a stand is more dependent on other factors than on site quality. For example, dominance is suitably expressed in Plot 7, which has a site index of 52, while Plot 8, with a site index of 57, is most unacceptable. It appears in this instance that the difference between these two stands can be ascribed to a difference in variation in age within the stands.

Variation in Age

The stands analyzed in this investigation were all relatively evenaged, since those with a spread in the age of individual stems of greater than 15 years were rejected. The variation in age, however, within stands accepted as evenaged is important. The coefficient of correlation between standard deviation of age and standard deviation of diameter in the natural stands of white pine studied is +0.73, as shown by Table I in the Appendix. A partial explanation of the differentiation or non-differentiation in stands

[8] Dominance is poorly expressed in Plot 35, which has a site index at 50 years of 75. Plot 35 is not stagnating, however, but is so widely spaced (260 trees per acre at 28 years) that competition between individuals has been weak and differentiation into crown classes very slight.

which have a site index of less than 60 is found in variation of age. Plot 8, which has a site index of 57 and is non-differentiated, is shown by the source data (see Appendix) to have a standard deviation in age of 1.66. In contrast, Plot 7, which has a site index of 52 and is differentiated, is shown by the source data (see Appendix) to have a standard deviation in age of 2.37.

The greater uniformity of plantations as compared to natural stands may be attributed, in part, to the fact that they are of one age. The dense stands of jack pine that come up after a fire are usually of one age and frequently stagnate. A variation in the age of the seedlings constituting the reproduction causes an irregularity from the beginning which is conducive to an early expression of dominance.

As previously stated, it was found that there was considerable variation in age within stands of white pine which could without question be accepted as evenaged. This variation can be explained in part by the irregular germination in white pine seed, but principally by the methods of regeneration cuttings used, which are discussed on page 14.

Germination of white pine is very irregular. Tourney and Stevens (1928) found that from an average of twenty-six germination tests with different lots of seed 40 per cent of the sound seed germinated within a period of 50 days. Hence, there is no brief period in which the greater part of the germination takes place, such as is found in jack pine, and furthermore a goodly number of the white pine seed hold over until the second year or longer before germinating. Such an unevenness is conducive to an early expression of dominance because, from the same seed crop, some of the individuals have become fairly well established before germination takes place in the seeds which require a more protracted rest period.

Of the stands studied, variation in age, as a helpful factor in causing an early expression of dominance, apparently is of the greatest importance in those stands which have a site index of less than 60 at 50 years. If the site index is 60 or above, the fertility of the site will normally allow an expression of dominance irrespective of variation in age.

DENSITY OF STOCKING

A high density of stocking apparently does not inhibit an expression of dominance in white pine where the site index at 50 years is 60 or higher. The effect of growing space on height is very small (Gevorkiantz and Hosley, 1929), and the factors of the site are such that a potentially fast-growing tree can exhibit this tendency. A low density of stocking, however, does act against a marked expression of dominance. This is seen in Plot 35, which has a high site index but a low standard deviation of diameter because of the wide spacing. Competition is not keen, and as a result there is but a slight division into crown classes. Hauch (1918) raises a point in this connection which is interesting, although it probably is not of major importance. He states that a widely spaced plantation because of lesser numbers normally carries fewer variations in genotype, and hence a weaker expression of dominance.

A high density of stocking does not have great influence on an expression of dominance in stands which have a site index at 50 years between 50 and 60, provided the variation in age is suitable. Variation in age will normally permit an acceptable number of trees per acre to dominate the remainder of the stand. If the variation in age on such a site is slight, however, a high density of stocking becomes of importance. The seedlings start evenly, and the factors of the site are such that all the stems within a stand compete on a more or less even basis. If there is ample growing space, uniformly distributed, early competition is lessened and the stand may not require thinnings until later in the rotation.

Density of stocking is of greatest significance in stands which have a low site index. If the density of stocking is high, the stands close at an early age and all trees suffer alike in the ensuing competition. If, however, the density of stocking is comparatively low and the stems are well distributed, a stand may develop, without stagnation, to such a size that a thinning can be made which will at least pay the costs of operation.

Density of stocking maybe either too high or too low for a suitable expression of dominance. A low density of stocking, although unfavorable for an expression of dominance on all sites, does not cause stagnation. High density of stocking does not appear to be a critical factor where the site index at 50 years is 60 or above. If the site index is below 6o, a favorable variation in age is desirable to compensate for a high density of stocking.

BIOTIC FACTORS

WHITE PINE WEEVIL

The white pine weevil *(Pissodes strobi* Peck) appears to attack dominant trees more frequently than trees of lesser vigor in the same stand. Graham

(1926), MacAloney (1930), and others concur in the opinion that the weevil seems to choose the most thrifty and rapidly growing, though not necessarily the tallest, trees in a stand. Peirson (1922) concludes that a weeviled tree loses about one-half of a year in height growth for each time it is attacked. If the weevil attacked trees indiscriminately, regardless of their individual vigor, it is conceivable that such attacks would aid in an expression of dominance. Since the weevil attacks and retards height growth in the dominant trees, it would seem that weevilingdoes not aid in an expression of dominance, but that, in a measure, it is a hindrance. The occurrence of weeviled trees among the dominants in a stand is probably due to the fact that the loss in height growth for one weeviling is relatively small, and the superior vigor of such weeviled dominants enables them to overcome the handicap.

SILVICULTURAL TREATMENT

The evenaged natural stands of white pine in southern New Hampshire are suited to clearcutting, seed tree ar shelterwood reproduction cuttings, or combinations of two or more of these methods. Ordinarily there is no conscious effort on the part of the operator to follow any particular system, the method being chiefly determined by expediency.

Clearcutting is the method most commonly used by commercial operators. Reproduction is haphazard, and its excellence or deficiency is governed by attendant conditions, largely fortuitous. A satisfactory understory of pine may already be present, but such stands are comparatively rare. If the cutting is made in a good seed year, reproduction in satisfactory numbers will very probably be established. A stand reproduced in this manner will tend to have a very narrow spread in age. Plot 8, which is of a relatively uniform age as evidenced by a standard deviation in age of 1.66, followed clearcutting and from evidence on the ground was established in a good seed year. More frequently, however, clearcutting is not made in a good seed year. Under such conditions, if there is a bordering stand of white pine seed trees, they will seed up smaller areas and the margins of larger ones. The resultant stand is usually produced from two or more seed crops and has a corresponding spread in age. Plot 7 was established in this manner and is marked by a considerable spread in age, the standard deviation being 2.37.

In a strict interpretation of the term there are few, if any, stands which have been reproduced by the seed tree method. The results following the abandonment of pastures often so closely parallel those obtained by seed tree reproduction that they are treated under this heading. In the past considerable acreage of pasture land has been abandoned on which scattered pine had been permitted to grow, presumably for the shade offered the cattle. When the pastures were allowed to revert to woodland, these scattered pine seeded up the area, and in some instances excellent stands were produced in this manner. The stands were usually established by two or more seed crops and, although essentially evenaged, they have a considerable range in age.

Stands reproduced by the shelterwood system, although rather limited in extent at present, are of chief interest from the silvicultural point of view because the shelterwood system is generally recognized as the best method to employ in natural regeneration of white pine. A more extended use of this system is dependent on a more general application of forest management.

Dana (1930) recommends the two-cut shelterwood system. He states that on light soils, such as those found in the area studied, the first cut should be comparatively heavy. Here there is less danger that the pine seedlings will be choked out by hardwoods, and with a relatively light overhead cover the second cutting can be deferred for 12 to 15 years. During an interval as long as this three or four heavy seed crops should be produced, and as a result there should be considerable spread in the range of ages. Plot 4 (see Plate I, NO.2) is located in a stand reproduced under shelterwood and has a standard deviation in age of 3.47. This stand has an average age of 8 yea.rs,and during the next few years the very young seedlings will be eliminated and the range in ages reduced.

From the above discussion it will be seen that a fairly broad distribution of ages within stands accepted as evenaged is perfectly normal for the region under consideration and that a more extended application of forest management will not alter but rather will intensify the situation. Since a variation in age is conducive to an early expression of dominance, this is indeed significant.

The natural stands observed which were excessively uniform were so limited·in extent that they do not warrant any special silvicultural attention. Past experience on the Yale Forest at Keene has been that natural stands of white pine can be held 'without thinning until they have developed sufficiently to pay their own way in the operation and yield a profit besides. This stage of development is normally reached in approximately the thirty-fifth year. It would seem that wherever the site index is as high aS,or higher than, the site index at Keene (45 to 65 feet at 50 years), there should be a sufficient expression of dominance over a management area as a whole to carry natural stands of white pine as far as the thirty-fifth year without thinning. At this time, with the economic barrier lifted, a series of thinnings should be initiated. Earlier thinnings would be beneficial, silviculturally, in some stands, but they would normally be difficult to justify on an economic basis.

An expression of dominance can be either increased or decreased by the technique employed in thinning operations. In a stand in which dominance is too strongly expressed,the thinning should take out the overvigorous individuals which are developing with large, branchy crowns. In Plot 22 (see Plate II, No. I) the large tree in the right foreground should be removed. Such a thinning would tend to make the stand more uniform. In stands in which dominance is weakly expressed the thinning is still in the dominants, but an attempt is made to favor the more vigorous individuals, and in this manner the expression of dominance is increased. Plot 8 (see Plate II, NO.2) is a stand which should be treated inthis manner. Stands occupying an intermediate position are thinned in a more flexible manner, the marker varying his technique as the stand varies.

The late Professor Tourney and the writer initiated an experiment in topping as an aid to dominance. A plot was treated on a 17-year-old, 4 × 4, Norway pine plantation in September, 1930. A check plot, adjoining it, was left untouched. The trees were of very nearly equal vigor, and comparison with near-by stands of Norway pine of the same age, but planted 6 X 6 and 8 X 8 feet respectively, showed that the 4 X 4 plantation was in the early stages of stagnation. The trees to be topped were chosen so as to leave the trees which were to be favored well distributed and with ample growing space. Two years' height growth was removed in topping the trees. It was hoped to obtain approximately the same benefits as those derived from an early thinning, but at a materially lower cost. The plot was examined by the writer in September, 1932, and it was found that one or more of the laterals on each tree had straightened up. At the end of 2 years the loss in height growth by the topped trees was so slight as to be of no practical significance.

When artificial regeneration is practiced, the method and technique emplayed have an influence on differentiation or non-differentiation in the resultant stands. Seeding approximates natural regeneration more closely than planting and should be more favorable toward an expression of dominance. However, the difficulties attendant upon establishing a stand by seed have so far prevented a general use of the method in this country.

The development of plantations is quite different in some respects from the development of natural stands. Meyer (1930) states that the diameter series of white pine in plantations tends toward positive asymmetry, and that natural stands have negative asymmetries of high value. The coefficient of asymmetry, if positive, denotes that there is a grouping of trees above the average diameter; if negative, that there is a grouping below the average diameter. This would seem to indicate that dominance is more favorably expressed in natural than in planted stands.

There are two factors operating which can bring this about. Planted stands are of one age and, therefore, any desirable effects from a slight variation in age are wanting. Also, there is always some elimination of the weaker seedlings in the nursery and before they are finally planted in the field. If transplant stock is used, there is always a certain amount of culling done during transplanting. If 3-0 root-pruned stock is used, the seedbed is thinned at the end of the second year and the retention of the better seedlings enters into the process. Planting stock is normally culled before shipment is made from the nursery, and this further increases its uniformity. Vigorous stock is necessary to withstand the shock of field planting, but it would seem that such a selective process must act against an expression of dominance.

In plantations the choice of spacing is closely linked with an ability to express dominance. In 1916 plantings of white pine were made on the Yale Forest at Keene, spaced 4 X 4, 6 X 6, and 8 X 8 feet respectively. In 1930 there was a better expression of dominance in the 4 X 4 than in either the 6 X 6 or the 8 X 8 spacing. Delayed crown closure in the 6 X 6 and 8 X 8 as compared to the 4 X 4 spacing has deferred the competition which will bring about a differentiation into crown classes, and it is quite probable that dominance will be better expressed in the wider spacings a few years hence. Experience on the Eli Whitney Forest at New Haven, Connecticut, has been that white pine in plantations spaced 6 X 6 feet is able to manifest an acceptable early expression of dominance on all site classes which have been planted. These plantations have been made on abandoned farm land, and the site quality is uniformly high. Norway pine, on the other hand, because of lower ability to express dominance, requires an 8 X 8 spacing even on the better agricultural soils. Early thinnings may be necessary to maintain a satisfactory growth rate in white pine planted 4 X 4 feet, especially on the poorer sites.

The use of a mixed plantation has some possibilities as a method by which an acceptable variation can be brought about. Two species are used, a primary and a secondary. It is planned that the primary species will produce the bulk of the crop trees. The secondary species is used as a filler and only rarely produces crop trees. Such a plantation was established on the Yale Forest at Keene in 1916 by planting white and Norway pine in alternate rows. This plantation was established on one of the poorer sites on the forest and 16 years after planting has, from a distance, the appearance of a pure Norway pine plantation. Tourney (1932) states that this initial advantage in height growth of Norway pine is maintained throughout the rotation on the poorer sites found at Keene. The white pine are acting as fillers and very few of them will enter into the final crop. In a plantation of this kind it may be more advisable to stagger the two species instead of mixing by alternate rows.

RELATIONSHIP BETWEEN DOMINANCE AND THE DEVELOPMENT OF WHITE PINE STANDS

A REASONABLY early expression of dominance is essential if a stand is to develop in a satisfactory manner without the aid of cultural operations. If dominance is weakly expressed and the stand develops without attention, stagnation is the inevitable result. If dominance is well expressed, the dominated trees drop out as the stand develops, trees which were intermediate in position become dominated, while trees in the upper canopy of lesser vigor slow up in height growth and assume an intermediate position. The stand through natural elimination obviates cultural operations.

The relationship between dominance and the development of forest stands is exceedingly complex, since any of the environmental factors which affect the one must of necessity affect the other. In the development of forest stands the forester is chiefly interested in the progress of the dominant trees. In this study the coefficient of correlation between average decennial growth on the radius of dominant trees and standard deviation of diameter was +0.87 on the natural stands which had a measurable diameter. This correlation points out that as the expression of dominance increases, there is a corresponding increase in the growth rate of the dominants. It is possible, however, to have rapid growth rate in the dominants and a low expression of dominance. This is particularly true of widely spaced plantations and is a question of density of stocking.

DENSITY OF STOCKING

To illustrate the relation between density of stocking and dominance, three cases are cited.

Plot 35 has a standard deviation of diameter of 0.87, which is low when compared to either planted or natural stands of the same age. This plot is on a good site (the site index is 75 at 50 years) and is making rapid growth. The average diameter for this plot is 9.0 inches as compared to 6.0 inches, which is the normal given by Frothingham (1914) for site I at 28 years (the age of Plot 35). Plot 35 then is on a good site, growing vigorously, and manifesting a poor expression of dominance. The reason is found in the low density of stocking for the age (260 trees per acre). Competition has not as yet been keen enough to bring about any marked expression of dominance.

The other extreme in density of stocking can be found in Plot 6. This plot has a standard deviation of diameter of 0.42 at 20 years of age, which indicates a weak expression of dominance.. The stand is in a poor state of vigor as is evidenced by an average diameter growth of 1.4 inches on the dominants for the decade 1919-1929. The density of stocking is high, being 22,750 trees per acre as compared to 2,060, the normal given by Frothingham (1914). The quality of the site (the site index is 44 at 50 years) also offers at least a partial explanation, since sterility of site has an inhibitory effect on the expression of dominance.

Plot 1 occupies an intermediate position. It has a standard deviation in diameter of 1.26 at 27 years, a density of stocking of 3,040, and a site index of 59 at 50 years. The density of stocking has been sufficient to bring about competition, and the site quality is high enough to permit an expression of dominance. The combination of factors met with on Plot 1 has brought about a desirable expression of dominance (see Plate I, No. 1). The dominants have been crowded sufficiently to prevent heavy branching, and yet they have been able to maintain their vigor. The diameter increment on the dominant trees for the decade 1919-1929 was 2.4 inches.

Basal Area

Normally a uniform stand has a greater number of stems per acre than a differentiated stand of like age. The higher density of stocking in non-differentiated stands quite frequently balances the greater size of dominant stems in differentiated stands. For this reason, in early life a non-differentiated stand may have as great or greater basal area than a differentiated stand. Whether or not a uniform stand has a greater basal area is dependent on the degree to which stagnation has progressed. This is illustrated by the following table:

BASAL AREA[9]

Plot No.	*Basal area per acre sq. ft.*	*Number of trees per acre*	*Average d.b.h. of plot inches*	*Average d.b.h. of dominants inches*	*Standard deviation of d.b.h.*	*Average age*
2	162	16,095	1.3	2.1	0.48	21
7	128	13,000	1.2	3.1	0.75	21
8	89	4,551	1.9	2.6	0.55	27
22	175	2,440	3.4	6.0	1.48	27

Plot 2 has a lower standard deviation of diameter and a lower average diameter of dominant trees than Plot 7, but it has a higher density of stocking, a higher average diameter for the plot, and a greater basal area. Stagnation has not progressed far enough in Plot 2 to allow Plot 7 to surpass it in basal area.

A comparison of Plots 8 and 22 shows that, although these two plots are of the same average age, stagnation has already affected the basal area of Plot 8. Plot 22 has the lower density of stocking, the number of trees per acre on this plot being 54 per cent of the number of Plot 8. The basal area, however, on Plot 22 is 197 per cent of the basal area on Plot 8.

Cubic Volume

The relationship between dominance and cubic volume is quite similar to that between dominance and basal area and for the same reasons. The

[9] From Source Data, Appendix.

following table gives the cubic volumes of the plots discussed under Basal Area:

CUBIC VOLUME[10]

Plot No.	*Cubic volume per acre cu. ft.*	*Number of trees per acre*	*Average d.b.h. of plot inches*	*Average d.b.h. of dominants inches*	*Standard deviation of d.b.h.*	*Average age*
2	2,358	16,095	1.3	2.1	0.48	21
7	1,755	13,000	1.2	3.1	0.75	21
8	1,571	4,551	1.9	2.6	0.55	27
22	3,291	2,440	3.4	6.0	1.48	27

Plot 2 with a standard deviation in diameter of 0.48 is more uniform than Plot 7 which has a standard deviation in diameter of 0.75. It also has a higher cubic volume than Plot 7. According to Figure 2A of Gevorkiantz and Hosley (1929), Plot 2 should continue to have a greater cubic volume than Plot 7 for 20 years. At approximately that time Plot 7 should pass Plot 2 in cubic volume.

Stagnation has already affected the cubic volume on Plot 8. As previously stated, Plot 22 has a lower density of stocking, the number of trees per acre on this plot being 54 per cent of the number on Plot 8. The cubic volume on Plot 22, however, is 210 per cent of the volume on Plot 8.

Quality of Wood

SIZE OF KNOTS

Tarbox and Reed (1924) state, in principle, that the density of stocking during the early life of a stand has a definite influence on the size of knots. A stand may have a moderately high density of stocking at 20 years of age. By the time this stand has reached the age of 60 years, the number of trees per acre will be considerably reduced. In this case many trees have died and disappeared which have served their purpose in pruning the remaining stand. In comparison, a stand with a relatively low initial density of stocking may contain as many trees per acre at 60 years as the first

[10] From Source Data, Appendix.

stand, assuming the same environmental conditions. The knotsize would be much larger in the second stand, because it had fewer trees per acre at the early age.

The size of knots produced is therefore a question of density of stocking. The effects of differentiated and non-differentiated stands on the size of knots are essentially the same when the stands are fully stocked. If, however, there has been too marked an expression of dominance (see Plate II, NO.1), heavy branches will be produced and consequently the knot size will be greater. The advantage of the stand in which early dominance has been suitably expressed lies in the concentration of comparatively clear wood on a relatively small number of dominants per acre.

SPECIFIC GRAVITY OF WOOD

Garratt (1931 : 110) states that specific gravity affords a direct index of strength and of other properties of wood. Consequently specific gravity is largely used as a basis for comparison between the growing conditions of a tree and the properties of the wood produced.

Tomlinson (1931) investigated the relation of crown class to specific gravity of white pine, his studies being confined to a 21-year-old plantation. He states that rate of growth, as expressed in rings per inch, has no effect on the specific gravity of white pine in planted stands of this age.

Paul (1930), after a study of white pine in a 32-year-old plantation, states, "Although the thinnings in the young planted stands of northern white pine have resulted in greater growth in diameter and height,the changes in specific gravity resulting in the codominant, intermediate, and overtopped trees are so small that they have no practical significance in the use of wood." It is to be noted that dominant trees were not included in this study.

Myer (1930) made a similar study on white pine in natural stands. The smallest tree considered in his data had a diameter of 14 inches. He could find no pronounced correlation between specific gravity and the number of growth rings per inch. He states that the samples with the highest density usually fell between the limits of 10-20 rings per inch. The density decreased outside of this optimum range, but the rate of decrease varied independently of the number of rings per inch.

The trend of results in the above investigations indicates that there is no consistent correlation between specific gravity and rate of growth in the wood of white pine. Apparently the concentration of wood produced upon a relatively few dominants has very little, if any, effect upon its specific gravity. Further research is necessary before a definite statement can be made.

SUMMARY AND CONCLUSIONS

1. The division into diameter and crown classes resulting from an unequal rate of growth in the trees of a pure, evenaged stand is termed an *expression of dominance.*

2. Standard deviation of diameter, breast high, was found to be a satisfactory criterion of an expression of dominance in stands of like age. A table of optimum ranges in standard deviation of diameter, breast high, for definite age classes is desirable. The data on which this paper is based are not sufficiently comprehensive to permit the delimitation of optimum ranges.

3. White pine possesses inherent ability to express dominance.

4. Dominance is expressed more favorably on good than on poor sites.

5. Variation in age within stands accepted as evenaged is conducive to an expression of dominance.

6. High density of stocking is a critical factor on the poorer sites only. Low density of stocking, because of lack of competition, acts against an expression of dominance on all sites, but is not accompanied by stagnation.

7. An expression of dominance can either be favored or checked by silvicultural treatment.

8. A stand in which there is an acceptable expression of dominance should be differentiated to such an extent that the dominant trees are capable of maintaining the greatest growth rate compatible with the development of well-formed crop trees. A weak expression of dominance, in closed stands, is accompanied by a comparatively slow growth of the dominants, while too marked differentiation produces dominants of poor form with large, heavy crowns.

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[11] U.S.D.A. = United States Department of Agriculture (Washington).

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APPENDIX

SOURCE DATA[12]

NATURAL STANDS OF WHITE PINE

	d.b.h. in inches	*Height in feet*	*Crown depth in feet*	*Crown spread in feet*	*Age in years*	*10-year radial growth in inches*
PLOT 1						
Average of plot	2.9	24.0	10.0	5.5	27	0.6
Average of dominant trees	4.8	29.0	15.0	9.5	29	1.2
Average of dead trees	1.6	18.0	4.0	2.5	23	0.5

Size of plot: 25 milacres. Site index: 59.

Trees per acre: live, 3,040, including 640 dominants; dead, 1,760.

Basal area per acre: 164 sq. ft. Cubic volume per acre: 2,650 cu. ft.

Standard deviations: d.b.h. in inches, 1.26; height in feet, 4.32; crown spread in feet, 2.55; age in years, 2.81.

[12] All site indexes are given at 50 years. Dead trees are those in evidence when plot was measured.

APPENDIX

	d.b.h. in inches	*Height in feet*	*Crown depth in feet*	*Crown spread in feet*	*Age in years*	*10-year radial growth in inches*
PLOT 2						
Average of plot	1.3	14.5	5.5	3.5	21	0.5
Average of dominant trees	2.1	18.5	9.5	5.0	22	0.8
Average of dead trees	0.8	11.0	2.5	2.0	19	0.3

Size of plot: 9 milacres. Site index: 54.
Trees per acre: live, 16,095, including 1,776 dominants; dead, 20,555.
Basal area per acre: 162 sq. ft. Cubic volume per acre: 2,358 cu. ft.
Standard deviations: d.b.h. in inches, 0.48; height in feet, 2.48; crown spread in feet, 1.18; age in years, 1.28.

PLOT 3

Average of plot	1.6	16.5	7.0	3.5	21	0.6
Average of dominant trees	2.6	21.0	11.0	5.5	22	0.9
Average of dead trees	1.0	13.0	4.0	2.0	20	0.4

Size of plot: 9 milacres. Site index: 63.
Trees per acre: live, 9,102, including 1,332 dominants; dead, 6,444.
Basal area per acre: 144 sq. ft. Cubic volume per acre: 2,095 cu. ft.
Standard deviations: d.b.h. in inches, 0.71; height in feet, 3.14; crown spread in feet, 1.57; age in years, 1.41.

PLOT 6

Average of plot	0.8	10.5	5.0	3.0	20	0.4
Average of dominant trees	1.6	14.5	9.0	5.0	22	0.7
Average of dead trees	0.3	6.5	2.5	1.5	17	0.1

Size of plot: 4 milacres. Site index: 44.
Trees per acre: live, 22,750, including 2,250 dominants; dead, 8,760.
Basal area per acre: 102 sq. ft. Cubic volume per acre: 1,612 cu. ft.
Standard deviations: d.b.h. in inches, 0.42; height in feet, 2.55; crown spread in feet, 1.20; age in years, 2.11.

PLOT 7

Average of plot	1.2	13.0	6.0	3.5	21	0.5
Average of dominant trees	3.1	20.0	12.5	7.5	24	1.1
Average of dead trees	0.5	9.0	2.5	2.0	21	0.2

Size of plot: 4 milacres. Site index: 52.
Trees per acre: live, 13,000, including 1,000 dominants; dead, 16,500.
Basal area per acre: 128 sq. ft. Cubic volume per acre: 1,755 cu. ft.
Standard deviations: d.b.h. in inches, 0.75; height in feet, 3.71; crown spread in feet, 1.86; age in years, 2.37.

	d.b.h. in inches	*Height in feet*	*Crown depth in feet*	*Crown spread in feet*	*Age in years*	*10-year radial growth in inches*
PLOT 8						
Average of plot	1.9	22.0	7.0	4.5	27	0.6
Average of dominant trees	2.6	27.5	12.0	7.0	28	0.7
Average of dead trees	1.4	16.0	3.0	2.5	26	0.4

Size of plot: 9 milacres. Site index: 57.
Trees per acre: live, 4,551, including 777 dominants; dead, 6,000.
Basal area per acre: 89 sq. ft. Cubic volume per acre: 1,571 cu. ft.
Standard deviations: d.b.h. in inches, 0.55; height in feet, 3.81; crown spread in feet, 1.89; age in years, 1.66.

PLOT 9						
Average of plot	2.5	23.5	12.0	6.0	27	0.7
Average of dominant trees	4.1	32.0	17.5	8.5	29	1.3
Average of dead trees	2.2	25.0	11.5	8.0	30	0.7

Size of plot: 6 milacres. Site index: 60.
Trees per acre: live, 4,843, including 835 dominants; dead, 4,500.
Basal area per acre: 187 sq. ft. Cubic volume per acre: 3,363 cu. ft.
Standard deviations: d.b.h. in inches, 1.11; height in feet, 5.60; crown spread in feet, 2.03; age in years, 1.62.

PLOT 10						
Average of plot	2.4	24.0	10.5	5.5	28	0.7
Average of dominant trees	4.8	32.0	19.0	8.0	30	1.0
Average of dead trees	1.2	17.0	4.0	4.0	26	0.2

Size of plot: 6 milacres. Site index: 57.
Trees per acre: live, 6,179, including 668 dominants; dead, 5,166.
Basal area per acre: 237 sq. ft. Cubic volume per acre: 4,562 cu. ft.
Standard deviations: d.b.h. in inches, 1.22; height in feet, 5.00; crown spread in feet, 1.67; age in years, 2.13.

PLOT 21						
Average of plot	3.4	28.0	10.5	5.0	28	0.7
Average of dominant trees	6.4	36.0	18.0	11.0	31	1.3

Size of plot: 25 milacres. Site index: 62.
Trees per acre: live, 2,400, including 240 dominants; dead, 1,540.
Basal area per acre: 179 sq. ft. Cubic volume per acre: 3,300 cu. ft.
Standard deviations: d.b.h. in inches, 1.50; height in feet, 4.77; crown spread in feet, 2.66; age in years, 4.08.

APPENDIX

	d.b.h. in inches	*Height in feet*	*Crown depth in feet*	*Crown spread in feet*	*Age in years*	*10-year radial growth in inches*
PLOT 22						
Average of plot	3.4	28.0	11.0	6.5	27	0.7
Average of dominant trees	6.0	35.5	18.0	12.5	29	1.2

Size of plot: 25 milacres. Site index: 69.
Trees per acre: live, 2,440, including 280 dominants; dead, 2,560.
Basal area per acre: 175 sq. ft. Cubic volume per acre: 3,291 cu. ft.
Standard deviations: d.b.h. in inches, 1.48; height in feet, 4.81; crown spread in feet, 3.32; age in years, 2.65.

	Diam. 6" above ground in inches	*Height in feet*	*Crown depth in feet*	*Crown spread in feet*	*Age in years*
PLOT 4					
Average of plot	0.5	2.5	2.0	1.5	8
Average of dominant trees	1.5	7.0	5.5	3.5	13

Size of plot: 6 milacres. Site index: 55.
Trees per acre: live, 28,056, including 2,672 dominants; dead, 1,333.

PLOT 5					
Average of plot	0.5	3.0	2.0	1.5	10
Average of dominant trees	0.9	5.5	3.5	2.5	14

Size of plot: 2 milacres. Site index: 40.
Trees per acre: live, 76,000, including 6,000 dominants; dead, 9,000.

PLOT 17					
Average of plot	0.3	2.5	2.0	1.5	11
Average of dominant trees	0.7	4.0	3.5	3.0	14

Size of plot: 4 milacres. Site index: under an overwood.
Trees per acre: live, 19,500, including 3,250 dominants; dead, none.

PLOT 18					
Average of plot	0.3	2.0	1.5	1.0	9
Average of dominant trees	0.6	4.0	3.5	2.5	13

Size of plot: 6 milacres. Site index: under an overwood.
Trees per acre: live, 25,718, including 5,511 dominants; dead, none.

	Diam. 6″ above ground in inches	*Height in feet*	*Crown depth in feet*	*Crown spread in feet*	*Age in years*
PLOT 19					
Average of plot	0.7	4.0	4.0	2.0	9
Average of dominant trees	1.4	6.5	6.5	3.0	10

Size of plot: 6 milacres. Site index: 68.
Trees per acre: live, 6,847, including 835 dominants; dead, 333.

PLOT 20					
Average of plot	0.9	5.5	5.5	2.5	9
Average of dominant trees	1.6	8.5	8.5	5.0	10

Size of plot: 6 milacres. Site index: 75.
Trees per acre: live, 7,348, including 835 dominants; dead, 666.

PLANTED STANDS OF WHITE PINE[13]

	d.b.h. in inches	*Height in feet*	*Crown depth in feet*	*Crown spread in feet*
PLOT 15				
Average of plot	1.7	12.0	9.5	5.5
Average of dominant trees	2.4	13.5	11.5	6.5

Size of plot: 25 milacres. Site index: 66. Age: 16 years.
Trees per acre: live, 2,480, including 680 dominants.
Basal area per acre: 44 sq. ft. Cubic volume per acre: 260 cu. ft.
Standard deviations: d.b.h. in inches, 0.65; height in feet, 1.78; crown spread in feet, 1.14.

PLOT 31				
Average of plot	2.0	11.0	9.0	6.5
Average of dominant trees	2.4	12.5	10.5	7.0

Size of plot: 25 milacres. Site index: 55. Age: 17 years.
Trees per acre: live, 1,280, including 480 dominants.
Basal area per acre: 30 sq. ft. Cubic volume per acre: 296 cu. ft.
Standard deviations: d.b.h. in inches, 0.52; height in feet, 1.60; crown spread in feet, 1.15.

[13] Age given is number of years from seed.

	d.b.h. in inches	*Height in feet*	*Crown depth in feet*	*Crown spread in feet*
PLOT 34				
Average of plot	2.6	12.0	10.5	8.0
Average of dominant trees	3.0	14.0	12.5	9.0

Size of plot: 25 milacres. Site index: 60. Age: 17 years.
Trees per acre: live, 680, including 280 dominants.
Basal area per acre: 25 sq. ft. Cubic volume per acre: 242 cu. ft.
Standard deviations: d.b.h. in inches, 0.52; height in feet, 1.94; crown spread in feet, 1.33.

PLOT 35				
Average of plot	9.0	35.0	25.0	17.5
Average of dominant trees	9.5	37.0	28.0	19.0

Size of plot: 50 milacres. Site index: 75. Age: 28 years.
Trees per acre: live, 260, including 140 dominants.
Basal area per acre: 59 sq. ft. Cubic volume per acre: 4,103 cu. ft.
Standard deviations: d.b.h. in inches, 0.87; height in feet, 3.44; crown spread in feet, 3.00.

PLOT 36				
Average of plot	8.0	47.0	25.0	15.0
Average of dominant trees	9.1	50.0	27.0	18.0

Size of plot: 50 milacres. Site index: 68. Age: 38 years.
Trees per acre: live, 360, including 180 dominants; dead, 60.
Basal area per acre: 65 sq. ft. Cubic volume per acre: 4,020 cu. ft.
Standard deviations: d.b.h. in inches, 1.39; height in feet, 4.48; crown spread in feet, 4.11.

PLOT 37				
Average of plot	9.6	50.0	23.0	13.0
Average of dominant trees	10.7	51.0	24.0	15.0

Size of plot: 100 milacres. Site index: 60. Age: 43 years.
Trees per acre: live, 360, including 190 dominants; dead, 20.
Basal area per acre: 185 sq. ft. Cubic volume per acre: 4,732 cu. ft.
Standard deviations: d.b.h. in inches, 1.51; height in feet, 4.28; crown spread in feet, 3.81.

	d.b.h. in inches	*Height in feet*	*Crown depth in feet*	*Crown spread in feet*
PLOT 38				
Average of plot	9.2	53·0	18.0	15·0
Average of dominant trees	10.6	56.0	20.0	17·0

Size of plot: 100milacres. Site index: 65. Age: 43 years.
Trees per acre: live, 430, including 190 dominants; dead, 40.
Basal area per acre: 201 sq. ft. Cubic volume per acre: 3,998 cu. ft.
Standard deviations: d.b.h. in inches, 1.84; height in feet, 4.85; crown spread in feet, 3.01.

PLOT 39				
Average of plot	2·5	13.0	13.0	8.0
Average of dominant trees	2.8	14·5	14·5	9·0

Size of plot: 25 milacres. Site index: 69. Age: IS years.
Trees per acre: live, 640, including 200 dominants.
Basal area per acre: 26 sq. ft. Cubic volume per acre: 312 cu. ft.
Standard deviations: d.b.h. in inches, 0.16; height in feet, 1.57; crown spread in feet, 1.41.

PLOT 40				
Average of plot	3·6	21.0	12.0	8·5
Average of dominant trees	4·8	24·0	14·0	10·5

Size of plot: 50 milacres. Site index: 75. Age: 17 years.
Trees per acre: live, 1,440, including 144 dominants; dead, 144.
Basal area per acre: 56 sq. ft. Cubic volume per acre: 2,442 cu. ft.
Standard deviations: d.b.h. in inches, 0.87; height in feet, 2.28; crown spread in feet, 1.74.

PLOT 42				
Average of plot	4.1	19·0	10.0	6·5
Average of dominant trees	5·6	23.0	13·0	12·5

Size of plot: 50 milacres. Site index: 70. Age: 22 years.
Trees per acre: live, 1,660, including 220 dominants; dead, 100.
Basal area per acre: 57 cu. ft. Cubic volume per acre: 2,136 cu. ft.
Standard deviations: d.h.h. in inches, 1.75; height in feet, 4.34; crown spread in feet, 3.32.

	Diam 6" above ground in inches	Height in feet	Crown depth in feet	Crown spread in feet
PLOT 26				
Average of plot	1.0	3.5	3.5	2.0
Average of dominant trees	1.3	4.5	4.5	3.0

Size of plot: 25 milacres. Site index: 53. Age: 9 years.
Trees per acre: live, 1,360, including 480 dominants.

	Diam 6" above ground in inches	Height in feet	Crown depth in feet	Crown spread in feet
PLOT 28				
Average of plot	1.1	3.5	3.5	2.5
Average of dominant trees	1.3	4.5	4.5	3.0

Size of plot: 25 milacres. Site index: 53. Age: 9 years.
Trees per acre: live, 720, including 280 dominants.

	Diam 6" above ground in inches	Height in feet	Crown depth in feet	Crown spread in feet
PLOT 29				
Average of plot	1.1	4.0	4.0	2.5
Average of dominant trees	1.3	5.0	5.0	3.5

Size of plot: 25 milacres. Site index: 55. Age: 9 years.
Trees per acre: live, 2,840, including 1,080 dominants.

TABLE I

COEFFICIENTS OF CORRELATION

Standard deviation of d.b.h. and standard deviation of crown spread	
Natural stands	+0.84
Planted stands	+0.83
Standard deviation of d.b.h. and standard deviation of height	
Natural stands	+0.84
Planted stands	+1.00
Standard deviation of d.b.h. and standard deviation of age	
Natural stands	+0.73
Standard deviation of d.b.h. and site index at 50 years[14]	
Natural stands	
Group 1	+0.64
Group 2	+0.55
Planted stands	
Group 1	+0.61
Group 2	—0.68
Standard deviation of d.b.h. and density of stocking	
Natural stands	—0.82
Planted stands[15]	
Group 1	+0.46
Group 2	—0.99
Standard deviation of d.b.h. and average 10-year growth on the radius of dominant trees	
Natural stands	+0.87
Average crown area[16] and average basal area	
Natural stands	+0.84
Planted stands	+0.94

[14] The plots are divided into groups of approximately the same age, because the standard deviation of d.b.h. varies with age while site index does not.

[15] Planted stands divided into two relatively evenaged groups.

[16] Crown area is used to designate the area of a circle which has crown spread as its diameter.

PLATES

PLATE I

No. 1. Plot 1, in which dominance is well expressed. This stand is sufficiently differentiated to permit vigorous growth in the dominants and is uniform enough to prevent the development of poorly formed trees. Average age of stand, 27 years. Photograph by A. R. Kienholz.

No. 2. Plot 4, a good expression of dominance. This area was regenerated by a shelterwood cutting. Average age of stand, 8 years. Photograph by A. R. Kienholz.

PLATE I

NO. I.

NO.2.

PLATE II

No. 1. Plot 22, in which dominance is too marked. Note the large branches on the dominant tree in the right foreground. Average age of stand, 27 years. Photograph by A. R. Kienholz.

No. 2. Plot 8, in which dominance is too weak. The stand is of low vigor, and stagnation has set in. Note the great uniformity in the size of the trees. Average age of stand, 27 years. Photograph by A. R. Kienholz.

PLATE II

NO. 1.

NO. 2.

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